

IGS Workshop 2006

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Fast Integrated Estimation of Huge GNSS Networks

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- **Capability of Software Packages**
 - ✓ *Number of Stations Limited to 100*
 - ✓ *Sub-network Mode*
 - ✓ *GFZ IGS+TIGA > 300 Stations*
- **Amount of Data**
 - ✓ *More Ground Stations and LEOs;*
 - ✓ *More Systems (GLONASS, GALILEO)*
- **Requirements on Products**
 - ✓ *Higher Precision*
 - ✓ *Higher Resolution*
 - ✓ *Lower Latency*
- **New Strategy**
 - ✓ *Enable Integrated Estimation of Huge GNSS Networks*
 - ✓ *Reduce # of Subnets and/or Improve Its Performance*

➤ Procedure of Processing One-Day Data

- ✓ *Iteratively Real-Valued Solution for Data Cleaning (LSQ)*
- ✓ *Integer Ambiguity Fixing Based on the Real-Valued Solution*
- ✓ *Fixed Solution (LSQ)*

➤ LSQ Estimation

✓ *Number of Parameters (Table)*

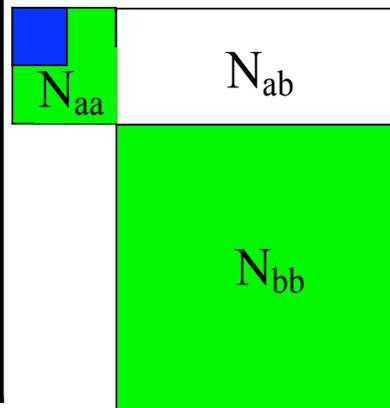
Parameters	Formula	Number
ERP		6
Station Coords	3*nsta	300
Satellite Orbits	15*nsat	450
Clocks	nsta+nsat	130
Zenith Delays	12*nsta	1200
Ambiguities	2*nsta*nsat	6000
Total		8086

* *nsta=100, nsat=30*

✓ *Inversion of Huge NEQ*

✓ *Fixing Decision Without STD ?*

➔ *Save Both Comp. Time and Memory*



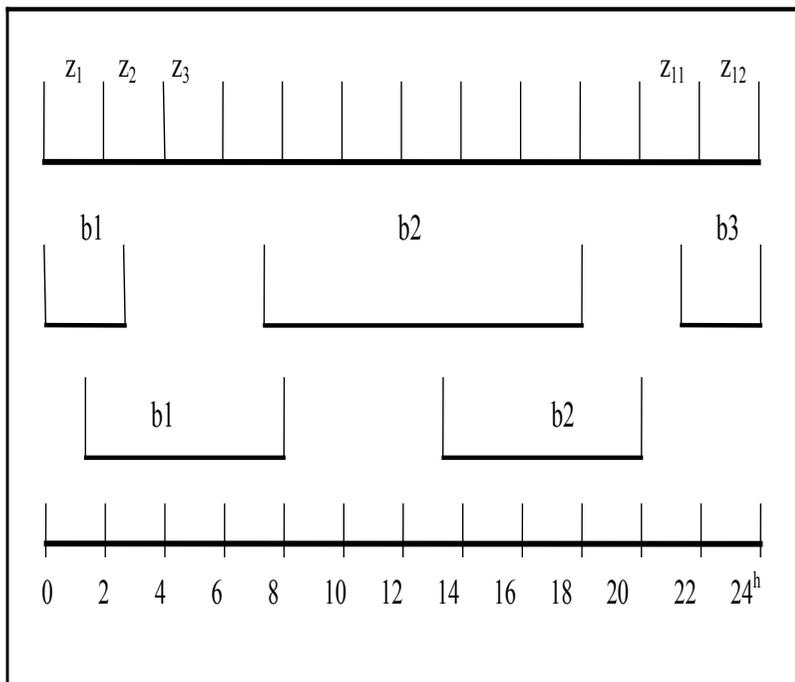
$$\begin{bmatrix} Q_{aa} & Q_{ab} \\ & Q_{bb} \end{bmatrix} = \sigma_0^2 \begin{bmatrix} N_{aa} & N_{ab} \\ & N_{bb} \end{bmatrix}^{-1}$$

$$b_i^{dd} = \bar{d}_i^T \bar{b}, \quad \sigma_{b_i^{dd}} = \bar{d}_i^T Q_{\bar{b}\bar{b}} \bar{d}$$

$$P(b_i^{dd} = n \text{int}(b_i^{dd}), \sigma_{b_i^{dd}}) > 1 - \alpha$$

- **Status of Parameters in LSQ: ACTIVE** (over its valid interval) **INACTIVE** (otherwise), Only 1 ZTD, 10 Amb. Active. Table
- **Inactive Parameter Can Be Eliminated Immediately. ONLY ACTIVE are kept in NEQ, 1/4 of Total.**

ONLY QUESTION: Ambiguity-Fixing without STD? YES



Parameters	Formula	Total	Active
ERP		6	6
Station Coordinates	$3 \cdot nsta$	300	300
Satellite Orbits	$15 \cdot nsat$	450	450
Clocks	$nsta + nsat$	130	130
Zenith Delays	$12 \cdot nsta$ $nsta$	1200	100
Ambiguities	$2 \cdot nsta \cdot nsat$ $nsta \cdot nobs$	6000	1000
Total		8086	1986

* $nsta=100, nsat=30, nobs=10$

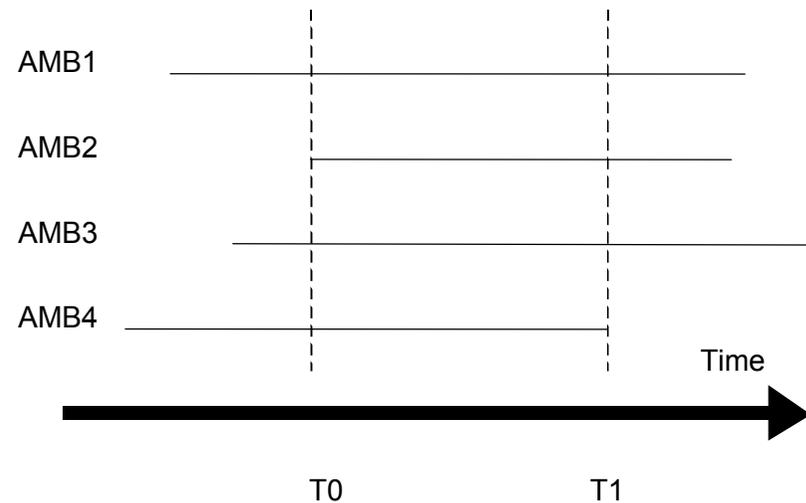
- **Wide-lane Ambiguities:** MW-Method
- **Narrow-lane Ambiguities:** based on Estimates only
 - ✓ Dense Network
 - ✓ Well-known Station Coordinates
 - ✓ Precise Modeling
 - ➔ STD of DD-ambiguity is very small, so that the fixing-decision mainly relies upon its estimate.
 - ➔ They can be fixed based on their estimates only
- **Possible Wrong Fixings** are detected by checking post-fit rms of observations related to each ambiguity

- **Define Baselines** Independent or All possible < 6000 Km
- **Baseline Level** : Make fixing decision for each possible DD-ambiguity over the baselines. From all fixable ambiguities over each baseline, select an independent set.
- **Network Level** : In case of searching over all possible baselines. An independent set is selected from all fixable candidates
- **Fixing Efficiency**: More than 95% independent ambiguities can be fixed.

RESULT : Fixing Information, Not Fixed Solution

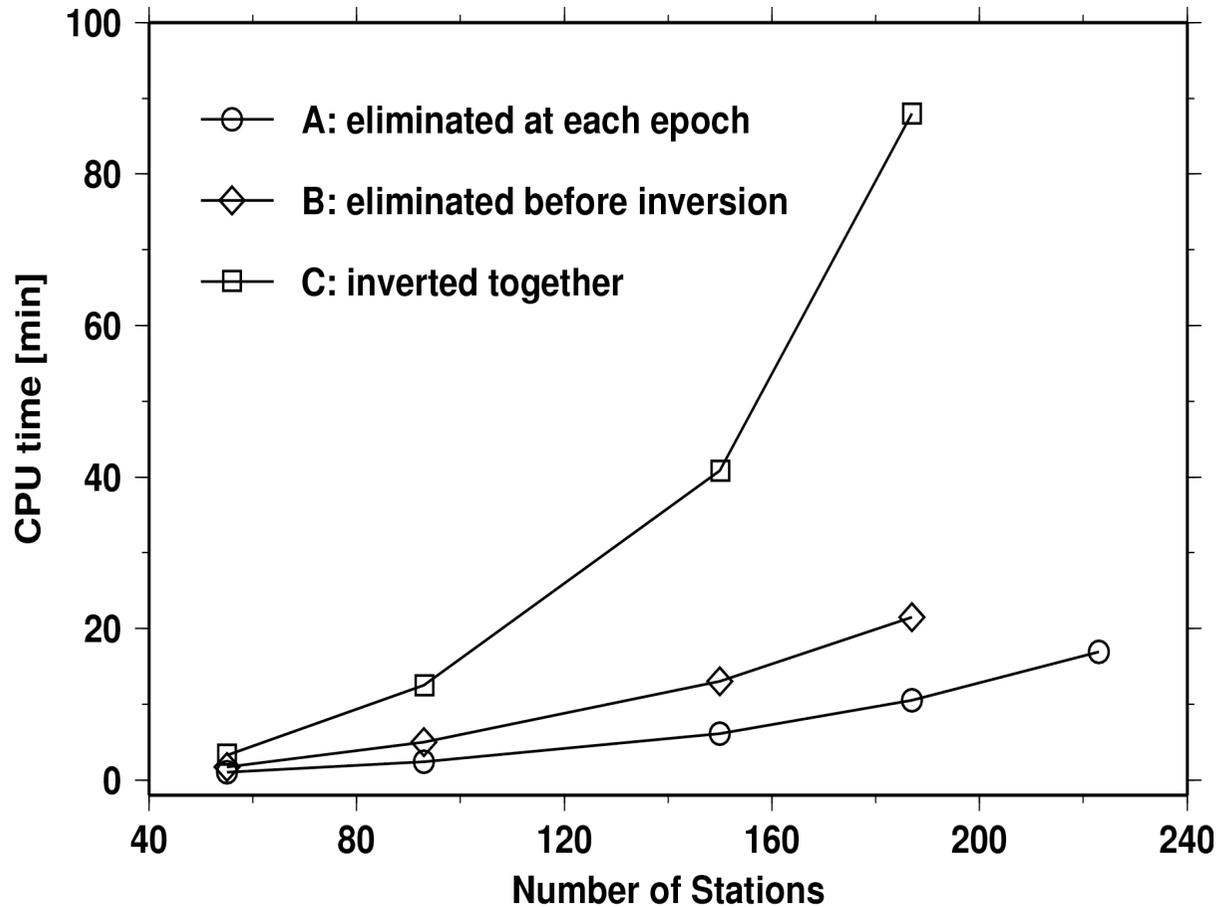
Fixed Sol. == Real-valued Sol. + Fixing Constraints

- **Fixed Constraint:** $v_i = b_{i,1} - b_{i,2} - b_{i,3} + b_{i,4} - B_i, \quad p_i$
- **When Contribute It to NEQ ?** So that ambiguity can be eliminated as in real-valued solution
 - ✓ Assign to each an **Epoch-Time == End-time of its related DD-obs.**
 - ✓ Reorder them according to their **Epoch-Time**
 - ✓ Add to NEQ as regular observations
- **Example (Epoch-time = T1)**
 - ✓ Cannot before T0, AMB2 is not yet introduced
 - ✓ Must before T1, so that AMB4 can be eliminated



- **Real-valued Solution** (iteratively for data cleaning, where inactive ambiguities and ZTD are eliminated and recovered late for residuals computation)
- **Ambiguity-Fixing** (based on real-valued solution, output ambiguity constraints according to their epoch time to a file)
- **Fixed Solution** (by adding the constraints, detect possible wrong fixing)
- **Repeat Last Two Steps** (for resolving more ambiguities, two iterations are sufficient)

- **EPOS Software at GFZ.**
- **Lunix, Pentium 4, 3.0 GHz, 1GB memory**
- **Strategies**
 - ✓ **A: AMB+ZTD active only;**
 - ✓ **B: eliminated before inversion;**
 - ✓ **C: inverted together with the others**
- **Networks: with about 50, 95, 150, 190, 225 stations; data sampling rate 300s**
- **Sampling Rate: networks with 95, 225 stations, data sampling rate 60s, 120s, 180s, 300s**



➤ Required Memory

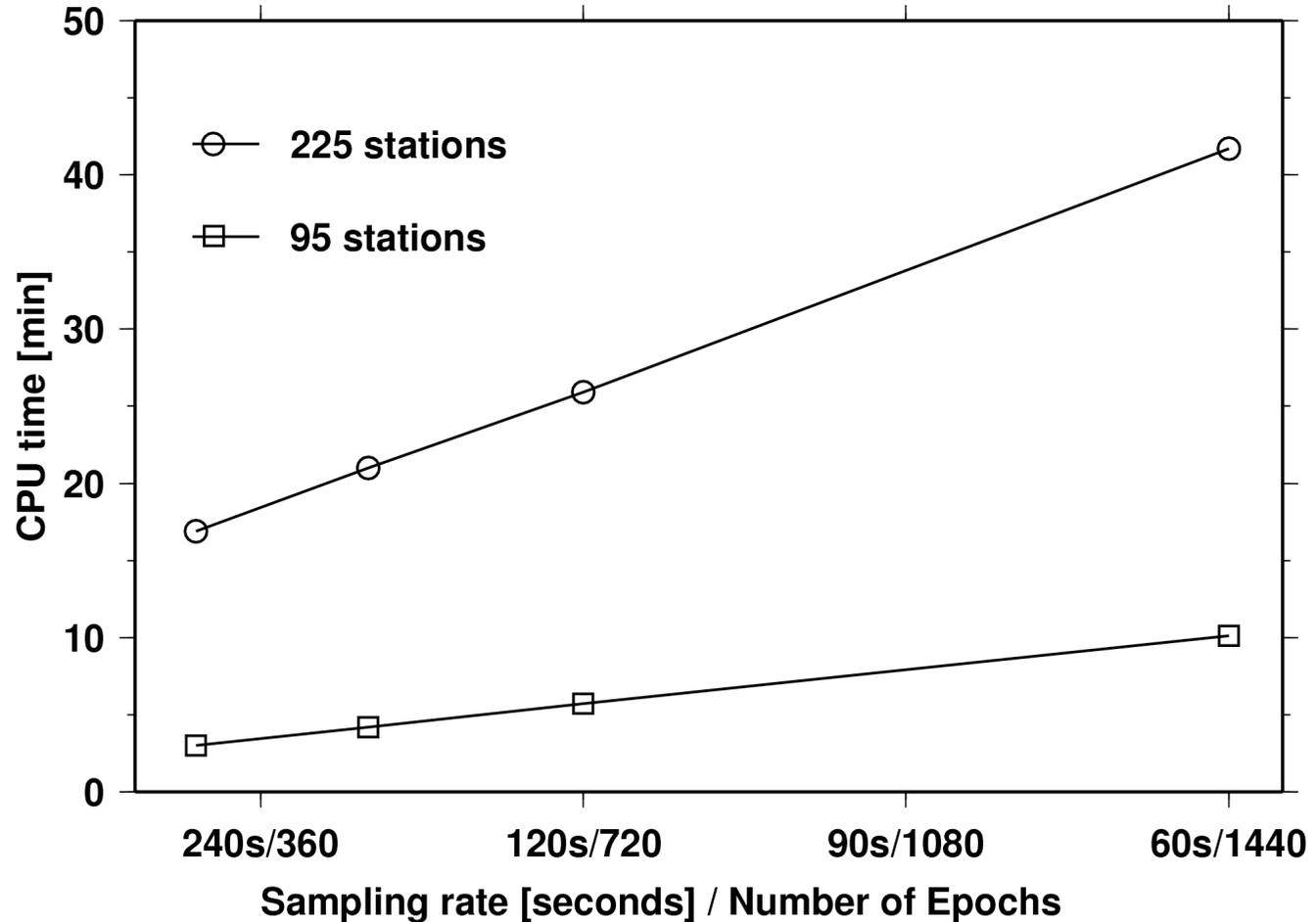
✓ For A, < 300 MB

✓ For B and C it grows rapidly, > 1 GB for 225 stations

➤ Computation Time

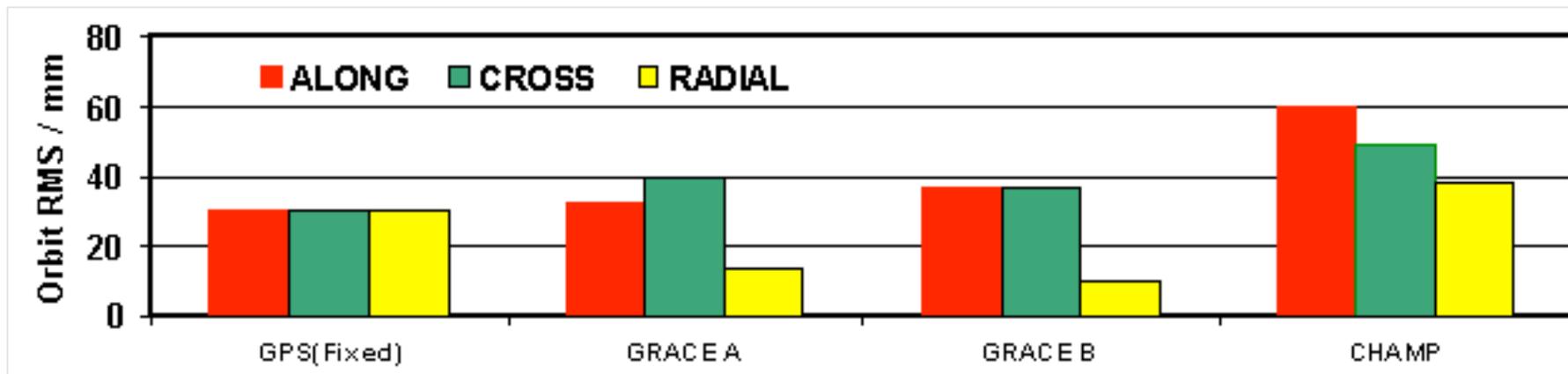
✓ For A, increases gently, rapidly for B and C

✓ A is half of B, eighth of C

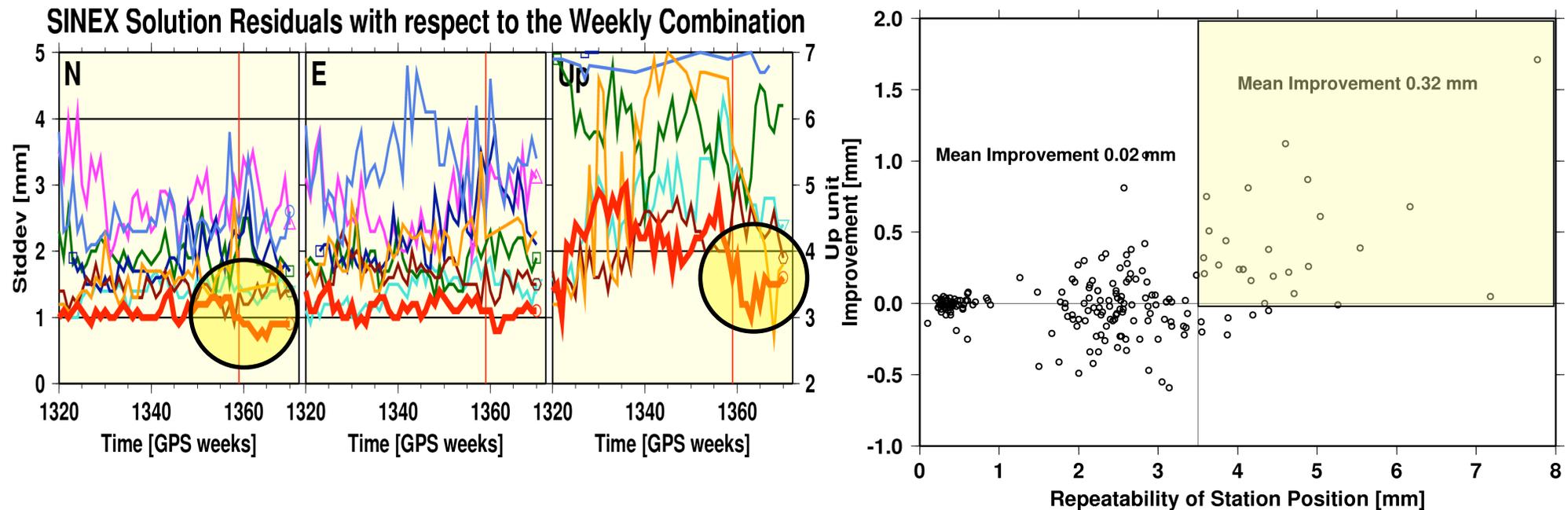


- **Increases linearly with sampling rate, faster for larger networks.**
- **Applicable if higher sampling rate is requested.**

- **DATA** : 40 Stations + GRACE + CHAMP, GPS+SLR(*)
- **Estimator**: LSQ, and SRIF; Active 1250/5000
- **Computation Time**: LSQ 15min, SRIF 45min on IBM Laptop 1.6GHz, Sampling Rate 1 min.
- **Orbit RMS**: (GPS wrt IGS, CHAMP wrt GFZ, GRACE wrt JPL)



- **Network rms in IGS combination reduced**
Switch to Integrated Mode since 02/2006 (1359)
- **Repeatability of station position improved**
Parallel run of Integrated and Sub-Network Mode



- **Reduces the number of parameters in NEQ to 25%, memory is not a problem anymore.**
- **Reduces computation time to at least one third.**
- **Introduced into routine at GFZ since 2006, Integrated Solutions reduce RMS in IGS combination and improve station repeatability**
- **Implemented into other estimator (SRIF)**
- **Enables integrated solution of huge network, up to 300 - 400 stations**
- **Enlarge sub-networks for very huge networks.**